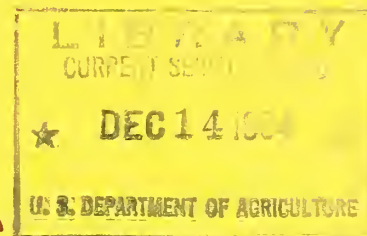


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BUTTERFAT SAMPLING in BULK HANDLING and COMPARATIVE MILK SOLIDS LOSSES



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This study was conducted with marketing research funds made available through the Agricultural Marketing Service.

The Farmer Cooperative Service conducts research studies and service activities of assistance to farmers in connection with cooperatives engaged in marketing farm products, purchasing farm supplies, and supplying business services. The work of the Service relates to problems of management, organization, policies, financing, merchandising, quality, costs, efficiency, and membership.

The Service publishes the results of such studies; confers and advises with officials of farmers' cooperatives; and works with educational agencies, cooperatives, and others in the dissemination of information relating to cooperative principles and practices.

SUMMARY

This study was designed to evaluate the present butterfat sampling procedures used in the bulk handling of milk. It also compared losses of milk solids with the bulk and the conventional can procurement system. The Rochester (Minn.) Dairy Cooperative furnished data for making the analysis on a contractual basis. The study was made in June and July 1953 and included 26 producers. Milk was shipped on an every-other-day basis from 25 producers and daily from one producer. Four drivers participated in the study.

The producers shipped a large volume of milk and had little variation in butterfat tests from shipment-to-shipment. The study analyzed the effect on producer tests of the blending action of farm tanks, position in the tank from which samples were taken, and whether fresh or composite samples should be used.

The study showed milk in farm bulk tanks when agitated for a minimum of two minutes was blended adequately. Differences in tests between selected positions in the farm tanks usually were not significantly larger than the difference in tests between duplicate samples from a single position. Customary practices employed by the bulk-tank truck drivers permitted a variation in agitation from 2 minutes to 6 minutes per farm tank. Variations in agitation time within this range did not affect adequacy of blending. Since bulk procurement procedures usually require at least 2 minutes for the necessary work after agitation is started, a minimum time requirement of 2 minutes would be adequate.

Variability between duplicate samples at the same position indicated the error was due to sampling and testing techniques. An additional amount of variability was evident when samples were obtained from different positions. However both of these sources of error were relatively small compared to the variation in the butterfat content between milk shipments for a given producer.

While reasonable efforts should be made to reduce the variability within the farm tank, there was little evidence that test results from any specific position would give consistently higher or lower results than other positions. There was a lack of complete homogeneity between duplicate samples taken from a single position and an additional variability when samples were drawn from different positions. Thus, this study showed a sample for testing purposes would be more representative if it consisted of several small samples from different positions rather than one large sample from one position. This would reduce the differences caused by the small variability among positions.

The test of composite samples was compared with the average of fresh milk samples for comparable time periods. For refrigerated samples the composite tests averaged .028 percent or slightly less than three-tenths of a "point" lower than the averages of fresh samples for the comparable

10-day period. The refrigerated composite was .038 or slightly less than four-tenths of a "point" less than the average of the fresh samples for the comparable 15-day periods.

For non-refrigerated samples, the tests of composites averaged .065 and .064 percent or more than six-tenths of a "point" less than the average of fresh samples for the comparable 10 and 15-day periods respectively. However, the amount that composite tests were reduced below the average of fresh tests for comparable periods was not the same for all producers. The composite test of producers with an average butterfat test of 4.67 percent was .09 percent or nine-tenths of a "point" below the average of the fresh tests for the 10-day period. For producers with an average test of 3.27 percent the composite test was only .016 percent below the average of the fresh tests for the 10-day period. Thus, the composite test results in addition to a tendency toward lower tests also failed to give comparable treatment to all producers.

Considering that producers using the bulk system have large volume shipments, even slightly lower test results would reduce producer payments. For example, with producers shipping 200 hundredweight of milk in a month, a reduction in test of only one-tenth of a "point" would reduce producer payments more than the additional cost of sampling and conducting fresh tests from each shipment.

This survey verified that the large volume milk shipments and the resulting small variation in butterfat content are basic in developing an efficient, low-cost testing program. A fresh sampling and testing program with little increase in cost reduced the possibility of underpayment to producers resulting from reduced butterfat tests of composite samples.

Further benefits in payments would come to producers by allowing some sample error and basing the producer test upon a limited number of fresh samples during the month. Such sample errors would be offsetting in the long run and would not normally reduce producer payments. The size of the sample error can be reduced by increasing the number of fresh tests conducted. Thus, the number of samples taken and their resulting costs to producers would be a policy decision by the plant management. This analysis of benefits to producers assumes that each producer would pay for the increased cost of the fresh sampling and testing program.

Comparative losses of milk solids between the bulk and conventional can procurement systems indicated that producer losses of milk solids were reduced by about .4 of a percent when the bulk system was used. This reduction in loss was evident for both butterfat and total milk solids.

On the other hand the purchaser of the milk paid for the total volume of milk in the farm tank. About .11 percent of the total butterfat and about .08 percent of the total solids remained in the farm tank with the customary bulk procurement procedures.

The bulk system shifted the loss of milk solids from the producer to the purchaser. In a cooperative organization the plant's increase in loss through bulk procurement would be shared by all producers. In the conventional can procurement system the individual producer carries his own losses.

The study did not consider the in-transit losses for either system. However, assuming about comparable losses in-transit, it appears that the bulk procurement system would reduce the overall losses of milk solids.

BUTTERFAT SAMPLING IN BULK HANDLING AND COMPARATIVE MILK SOLIDS LOSSES

By

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The bulk handling of milk -- that is, using bulk tanks on the farm and bulk tank trucks to carry the milk to the plant rather than the conventional 10-gallon can system -- has been increasing in importance in recent years. Persons in the dairy industry generally understand the new system; however, it has not been analyzed in detail for its effect upon the milk producer or the plant operator.

This study analyzed some of the practical butterfat sampling and testing problems in bulk handling and compared losses of milk solids in the conventional can system with those in the bulk procurement system. It was conducted as a project under the Agricultural Marketing Act of 1946.

With the bulk system, milk samples for testing must be obtained from each individual farm tank. Thus, adequacy of milk blending within each tank becomes important in obtaining a representative sample.

This report on the study supplements previous information on producers' daily variation in butterfat tests by the conventional can procurement system gathered by the Farmer Cooperative Service. Its Bulletin 5, "Developing Butterfat Sampling and Testing Programs," gives a detailed analysis of butterfat sampling and testing problems with the conventional can procurement system.

At present, bulk milk handling has been largely confined to producers with a larger than average production. Also the milk shipments were normally on an every-other-day basis. The previous study demonstrated that large volume shipments reduced variations in producers' daily butterfat test. These two factors were additional consideration in supplementing the information from the previous study. The study was conducted during June and July of 1953.

The drivers determined the volume of milk by measuring the milk in the farm bulk tank. They used a calibrated measuring device and through an appropriate scale converted the measurement to a weight basis. Thus, milk solids left in the farm tank became a plant loss. In the conventional can system, each individual carries the losses of milk solids until the milk is weighed and received at the plant. It became important to determine the shift in milk solids loss from the producer to the milk plant with the bulk system.

Laboratory personnel from the Rochester Dairy Cooperative of Rochester, Minn., made the necessary butterfat determination. Drivers on the bulk

procurement routes obtained the milk samples for testing purposes. Bulk procurement was on an every-other-day basis from 25 producers with an additional producer on a daily basis.

Four drivers operated the bulk tank trucks, picking up the milk from these producers. Each driver followed the same instructions throughout the study. (See Appendix A for the detailed instructions.)

We selected comparable positions within each tank to determine possible differences in butterfat content of the milk at those locations. (Figure 1.) The driver obtained one sample from each of the selected positions in a tank on each of his milk pick-ups. In addition, he obtained an additional duplicate sample from one of the three positions each time. The samples taken for this study were in addition to the customary sample where the producer's milk was taken from each of the bulk farm tanks and combined in a single sample to determine the test for producer payments.

At the beginning of the study we established the agitation time for blending the milk for each tank. We used this same amount of agitation time for each subsequent sampling from that tank. Agitation time was defined as the time when the agitator was started until the first sample was taken. This time varied from 2 to 6 minutes from tank to tank but it was constant for a given tank.

Drivers carried the milk samples obtained from the producers' tanks in a sample bottle rack in the bulk tank truck, cooling them by ice to prevent deterioration. Upon arrival at the plant, drivers placed the samples in the refrigerator. On the following day, the laboratory personnel made butterfat determinations by the Babcock method and took samples for the composites. The laboratory took composites from the customary sample and made a test from each delivery from this sample by prescribed procedures. (See Appendix A.)

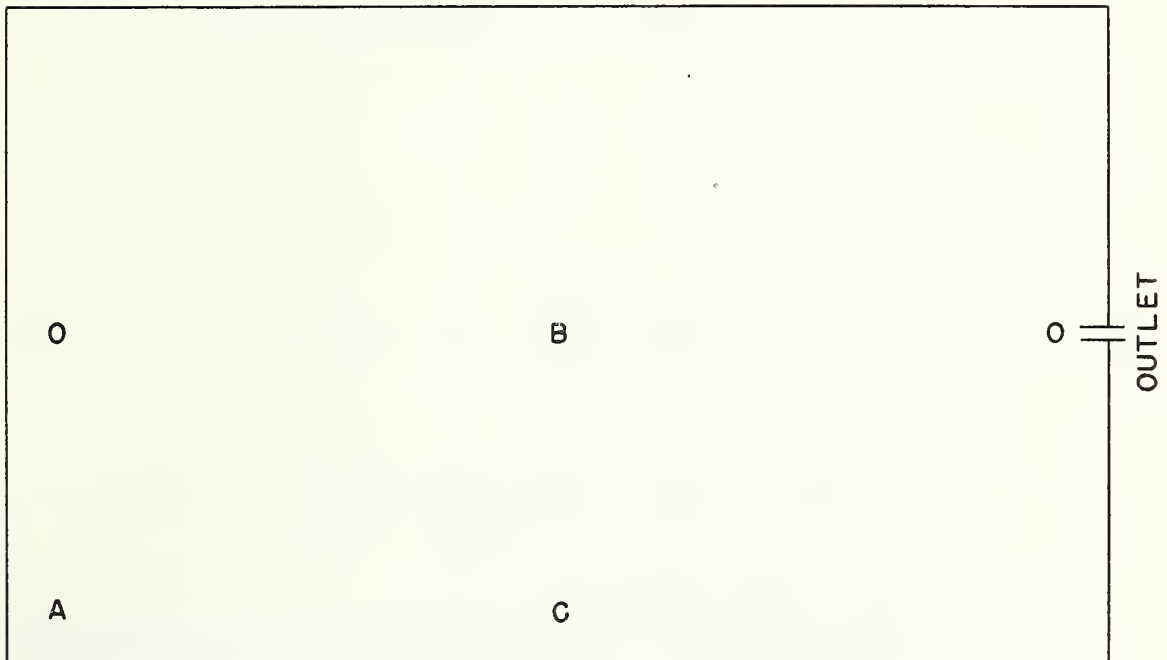
VARIATIONS IN TEST

The 26 producers averaged 1,376 pounds of milk for each shipment on an every-other-day basis with an average butterfat test of 3.82 percent. Producers' shipments varied from less than 800 pounds for each shipment to over 2,000 pounds. (Table 1.) During the two months of the study, both volumes and tests varied. These fluctuations were the results of normal changes in the production conditions.

Nature of these Variations

Butterfat tests of milk samples taken from consecutive shipments from the same producer had some variability. This variability resulted from (1) the change in butterfat content of the herd's production; (2) the variability caused by inadequate blending of the milk which prevented obtaining a representative sample; and (3) the variability in tests caused by testing procedures used, such as the rounding error in reading

FIGURE 1
 DIAGRAM OF FARM TANK AND POSITIONS FROM WHICH
 SAMPLES WERE OBTAINED



the Babcock test, the human factor and/or variation in the testing procedures. The relationship between these components of variability is summarized in Appendix B, Table 1, for each producer.

Of the three main sources of variability the dairy plant operators can control both adequacy of blending and testing procedures to some extent. They cannot control changes in the herd's butterfat content. This is the largest source of variability; and it becomes the major consideration in developing a sampling and testing program after the other two sources of variability have been reduced as much as possible.

The variability in butterfat tests was measured by computing the standard deviation. This is the square root of the average of the squares of the deviation of each test from the mean of the fresh sample tests for the period. The standard deviation is a measure of spread or dispersion. If most of the tests are near the mean, the standard deviation will be small, while if the tests are spread out over a considerable range, the standard deviation will be large. Further, on the basis of probability, the percentage of tests falling within plus or minus 1, 2, and 3 standard deviations from the true average will normally be approximately 68, 95 and 99 percent, respectively. For example, 68 percent of all tests would normally fall within plus or minus one standard deviation from the average.

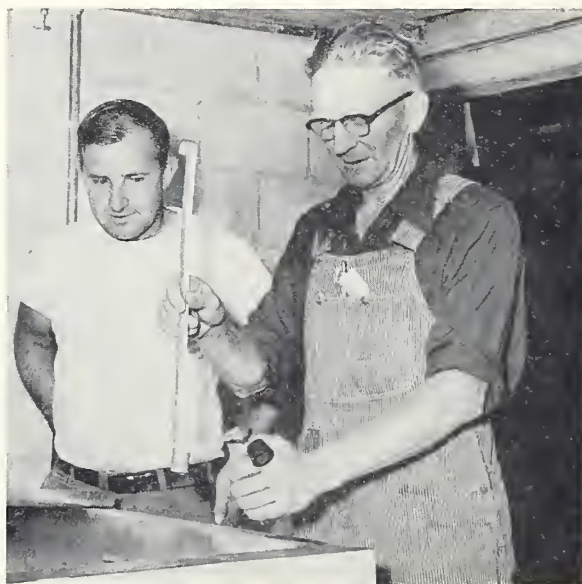
Table 1. - *Volume and test of producers' milk shipments, June - July 1953*

Butterfat test	Number of producers with milk volume of: ¹				
	Less than 800	800 to 1199	1200 to 1599	1600 and over	Total
Less than 3.20--	-	-	1	2	3
3.20 to 3.59----	-	2	8	3	13
3.60 to 3.99----	-	2	1	-	3
4.00 to 4.39----	-	-	1	-	1
4.40 to 4.79----	1	3	1	-	5
Over 4.80-----	2	-	-	-	2
Total-----	3	7	12	5	27

¹Volume is the average quantity of milk (in pounds) per producer shipment for the two-month period.

Actual Changes in Butterfat Content

The milk shipped by each individual producer had some variation in butterfat content. About one-half of the producers had a standard deviation in butterfat tests of less than .12 percent butterfat. (Table 2.) This variability was less than was reported in FCS Bulletin 5 with the study of sampling and testing for the conventional can procurement system. For all of the 26 producers included in this study the average standard deviation was .14 percent in June and .13 percent in July. Variability for the average of these producers was about 60 percent as large as that reported in FCS Bulletin 5 and in other studies.¹ The decrease in variability can be explained by (1) the large volume of milk from each producer and (2) the every-other-day shipments. Other causes for the decrease in variability might be environmental differences among producers.



Producer observing the procedure used in sampling milk in farm bulk tanks by the Rochester (Minn.) Dairy Cooperative which furnished data for this study.

¹Herrmann, L. F. et al. Sampling Routines and the Accuracy of Patrons' Butterfat Tests, U.S. Agr. Mar. Ser. Marketing Research Report No. 66, 1954.

Table 2. - *Distribution of producers by the amount of variability in butterfat tests, June - July 1953*

Standard deviation	Distribution of producers			
	June		July	
	Number	Percent	Number	Percent
Less than .100-----	7	26.9	9	34.6
.100 - .119-----	6	23.1	6	23.1
.120 - .139-----	6	23.1	3	11.5
.140 - .159-----	2	7.7	1	3.8
.160 - .179-----	1	3.8	1	3.8
.180 - .199-----	0	0.0	3	11.6
.200 or more-----	4	15.4	3	11.6
Total-----	26	100.0	26	100.0

Producers' milk deliveries with highly variable tests had relatively high butterfat tests and low volume. (Table 3.) However, low volume seemed to have less effect upon variability in test than did high butterfat test, since combined low-test, low-volume did not appreciably increase the variability. With conventional can procurement it was found that variable daily tests were associated with high butterfat content, and variability generally increased with low volume deliveries. However, there was little decrease in variability as volume of milk delivered increased above 300 pounds per day. Thus, on this basis it could be expected that volume would be less important in tank procurement and that level of butterfat content would be relatively more important.

Table 3. - *Comparison of butterfat content, volume of milk and average variability¹ in butterfat test for individual producers² June - July 1953*

Test	Variability when average volume shipped is:							
	Less than 1200 pounds		1200 to 2000 pounds		Over 2000 pounds		Average	
	No. of producers	Variability in test	No. of producers	Variability in test	No. of producers	Variability in test	No. of producers	Variability in test
Over 4.0-----	6	.179	2	.174	0	-	8	.178
3.5 - 4.0----	3	.109	7	.113	0	-	10	.112
Less than 3.5	1	.118	3	.139	5	.096	9	.113
Average or total ³ -----	10	.152	12	.130	5	.096	27	.132

¹Average variability is shown as standard deviation of butterfat percent computed from the variances.

²The producer having daily shipments was considered as equivalent to two producers.

³Averages were computed from the square root of the average variance.

Procedures Used

To find the differences in test results caused by the procedures being used, drivers took a duplicate sample from one position in each farm tank for each delivery during the course of the study. Since the samples were obtained while the milk was being agitated, the sample was not a true duplicate of the same milk, but only of milk at the same position.

Although this variability in test results was caused by a combination of factors, it indicated the amount of variability that would result from repeated sampling at the same position. The amount of the standard deviation fluctuated from producer to producer and ranged from a high of .114 to a low of .025 percent.

Differences Due to Non-Representative Samples

We determined how adequately each sample represented the total volume by estimating the variation in test results from samples obtained at different positions. Factors causing variations in test results of duplicate samples from the same position also cause variation in results of samples obtained from different positions. Thus, the variation in test results caused only by differences in position should consider the variability caused by duplicate sampling from the same position. The statistical procedure for making these estimates is given in Appendix B. The additional variability caused by position differences increased the average standard deviation in test by an estimated .031 percent. The estimate of the amount of the increase in variability fluctuated from an actual decrease in variability of .007 percent to an increase in variability of .116 percent for duplicate samples from one position. However, on the average, the additional variation caused by differences between positions was less than the variability caused by the difference between samples from the same position.

An analysis of variance indicated that for 7 of the 26 producers the variability caused by position differed from zero by an amount greater than could be expected due to chance alone. However, even though these differences were statistically significant the actual amount of the variability caused by position differences was small. (See Appendix B, Table 1.)

Size of farm tanks varied from 150 gallon to 600 gallon tanks, with 20 tanks in the 200 or 300 gallon sizes. Significant differences between samples from the different positions was not consistently associated with either size or type of farm tank. Further, while agitation time varied from 2 to 6 minutes, there was no decrease in the amount of variability with increased agitation for this range in agitation time.

Three of the eight producers with tests of 4.4 percent or higher had significant differences among positions. Thus, producers with a high average butterfat content tend to have greater variability due to position differences.

Where significant differences between positions was evident, we found that such differences were caused by one position being high or low relative to other positions for one or two shipments. This position difference was not consistent for each shipment. Thus, the small difference between duplicate samples from the same position caused the statistical test to be significant.

Relative Importance of Factors Causing Differences

The components of variance resulting from changes in the butterfat content of the milk was estimated from the analysis of variance. (See Appendix B.) For the average producer for the 2-month period, the estimated standard deviation was .146 percent as a result of the actual variability in the butterfat content. If this had considered the components of variance resulting from position differences and the procedures used, the variability in tests would have been .156 percent.

For the 2-month period the variability was slightly greater than for either June or July when the average standard deviation was .14 and .13 percent, respectively. The increased variability was caused by including the extreme differences in test for the 2-month period as computed from the average for the 2 months. While this increased the variability in actual butterfat content relative to a 1-month period, the increased number of observations made more valid the estimation of the components of variance caused by sampling and testing procedures and position differences. These values would not be affected by changes in average butterfat content over the 2-month period.

The analysis of variance clearly demonstrates the causes for variability in butterfat test. Knowledge of the causes for variability can be used in developing a sampling plan. Appendix B, Table 1, indicates that by far the most important cause of variability in tests was the actual change in butterfat content. The amount of variability fluctuates among producers for each of the factors causing variability. The relative importance of each factor also changes but for all producers the most important source of variability was the actual change in butterfat content.

To reduce the error of sample averages, a sampling and testing program should give major consideration to the actual change in butterfat content. That is, the estimate of the true average can be improved to a greater degree by sampling and testing additional deliveries than by obtaining more samples each day or duplicating the testing of a given sample. However, since some variability in test is caused by differences among positions and by differences between samples at the same position, the estimate of the true test can be improved by obtaining several samples from the farm bulk tank from different positions and combining them into a single sample.

This procedure reduces the variability caused by differences between samples obtained from milk in the same tank since such a sample will be more nearly representative of all milk in the tank. This additional

sampling would not appreciably affect the cost of the program. While conducting additional tests from each shipment would be effective in reducing the within position component of variance, it would entail increased costs. Such additional tests would be more informative if used to test samples from additional shipments.

In summary, the differences between positions were:

1. Small in relation to the variability in the butterfat content of producer shipments.
2. Largely the result of one or two days when differences between positions was far larger than normal.
3. Largely the result of sampling and testing error. Since drivers took samples while the milk was being agitated, it can be expected that minor variations exist from repeated sampling from the same position.
4. More frequent for producers' shipments with a high butterfat content.

Thus, a sample will be more nearly representative of the total volume of milk if several small samples from various positions in the tank are taken and combined into a larger sample rather than if only one large sample is taken. The quantity for testing can be then drawn from the larger sample.

COMPARISON OF COMPOSITE AND FRESH SAMPLES

In addition to determining the adequacy of milk blending, tests of composite samples were made to furnish further information as to the most appropriate type of sampling and testing program. Both refrigerated and non-refrigerated composite samples for 10 and 15-day periods were tested. See Appendix A for details on the compositing procedure.

Laboratory technicians made butterfat determinations from the customary sample taken from each delivery. They also took samples for the composites from this sample. Thus, comparisons could then be made between composites and fresh samples as well as the comparisons between various types of composites under different types of storage conditions. The average butterfat tests of fresh samples for the respective periods were used as the standard of comparison.

The analysis compared the simple average of the test of fresh samples over the compositing period. For example, in comparing the 10-day composite, the average of the fresh sample for each comparable 5-consecutive delivery period was used. Thus, for each month there were three comparisons for each of the two types of 10-day composites and two comparisons for each of the two types of 15-day composites.



Checking milk in the farm tank for odor and normal appearance before pumping it into the tank truck was one of the jobs of the four drivers who helped conduct this butterfat sampling survey.

When all producers were considered as a group, it was found that the average of composite samples gave lower test results than averages of fresh samples for the same period. (Table 4.) The amount of the average reduction in test was larger for 15-day composites than for 10-day composites on the average. Non-refrigerated samples showed average lower tests results than refrigerated samples. However, the amount of the average reduction in test for the non-refrigerated 15-day composites did not increase in relation to the non-refrigerated 10-day composites when all tests were considered as a group.

The Babcock test is a reasonably accurate and rapid method for making butterfat determinations. However, in determining the amount of reduction in test due to the compositing procedure the variability caused by the testing procedure becomes important. To be significant the

Table 4. - Comparison between butterfat test results from fresh, 10-day, and 15-day composites and between refrigerated and non-refrigerated composite samples, 26 producers, June and July 1953

Type of composite	Number of comparisons	Proportion of composite tests below average of corresponding fresh samples	Reduction in test for composites in relation to corresponding average test of fresh sample	Standard error of the mean difference ¹
10-day refrigerated-----	156	² 59.6	⁴ -.028	.0071
10-day non-refrigerated-	156	³ 84.0	⁴ -.065	.0064
15-day refrigerated-----	104	³ 73.1	⁴ -.038	.0078
15-day non-refrigerated-	104	³ 81.7	⁴ -.064	.0085

¹The standard error indicates that normally about 68 percent of the observations will be within plus or minus the amount specified.

²A proportion as large as indicated could be expected in less than 5 out of 100 times due to chance alone.

³A proportion as large as indicated could be expected in less than 1 out of 100 times due to chance alone.

⁴Highly significantly larger than the standard error of the mean differences.

downward reduction in test must exceed the variability resulting from the procedures used by an amount greater than can be expected due to chance alone.

Each composite test was compared with the average test of fresh samples for the same corresponding period. The analysis was based upon 156 comparisons for each type of 10-day composites, and on 104 comparisons for each type of 15-day composites.

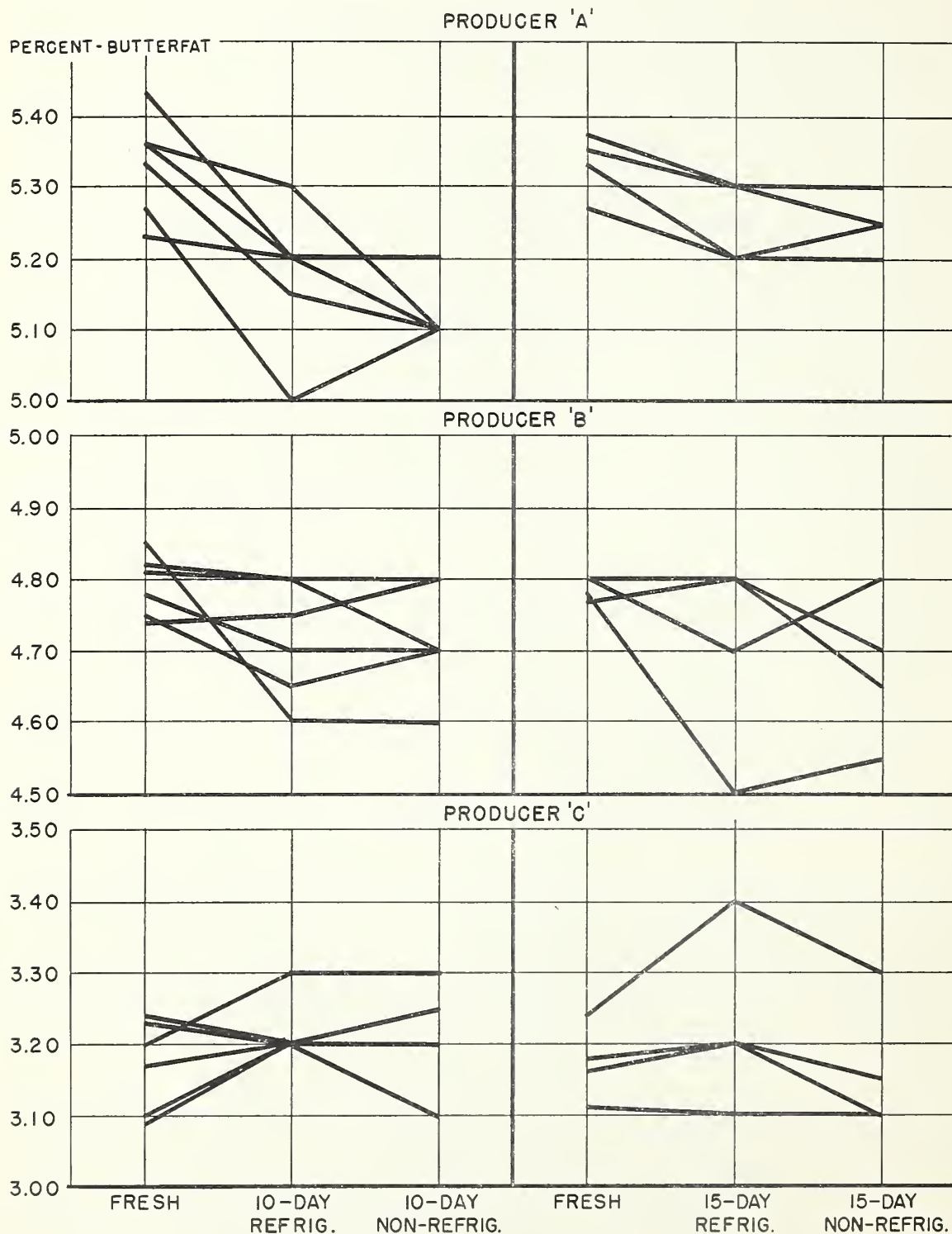
Comparisons between composite tests and the averages of fresh samples for the same corresponding period could be expected to show some differences since using the Babcock test results in a small error. If this were the only consideration it would be expected that tests of composite samples would be about equally distributed above and below the average of fresh tests for same period. However, when the comparisons were made, the proportion of composite tests below the average of fresh tests was in excess of the proportion that could be normally attributed to chance alone. (Table 4.) The proportion of composite tests falling below the fresh test averages increased when the compositing period was increased for the refrigerated samples. Further, the non-refrigerated composite samples had a larger proportion of tests below the average of corresponding fresh samples than the refrigerated samples. On the basis of the proportion of tests falling below the average of fresh tests, the compositing procedure gave lower test results more frequently than could be expected due to chance variation.

The amount attributable to compositing is difficult to determine since errors were evident in both the compositing procedure and in the Babcock method. Reductions in test, resulting from the compositing procedure for significance should exceed the standard error of the mean differences. The amount of reduction in test was found to be highly significant for all types of composites. Thus, the size of the reduction in test combined with the high proportion of composite tests falling below the fresh test furnished clear evidence that the compositing procedure in general reduced the producers' test results.

Figure 2 graphically demonstrates the comparison between fresh and various composite tests. A producer with high, medium and low butterfat content was selected. For each producer there were six comparisons for each type of 10-day composite and 4 for each type of 15-day composite. The lines drawn on the figure represent these comparisons. The producer with high butterfat content had the largest and most consistent reduction in test, while the producer with the low butterfat content had little reduction and the amount of test reduction varied.

Figure 2 further demonstrates that on the basis of any single comparison between fresh and composite samples, the presence and amount of reduction may be different than for another comparison. In general, however, reduction in test did exist. The fluctuation in the amount of test reduction among producers and even for a given producer makes adjustments in composite test to coincide with fresh tests subject to important errors.

FIGURE 2
COMPARISON BETWEEN TESTS OF FRESH, 10-DAY, AND 15 DAY
COMPOSITE FOR THREE SELECTED PRODUCERS



The amount of reduction in test was not comparable for all producers. Analysis of variance of the differences between various composites and averages of test of fresh samples for comparable periods indicated that differences among producers were highly significant. Samples from milk shipments with a high average butterfat content had a greater reduction in test due to the compositing procedure than did samples from shipments with low average butterfat content. (Table 5.) When producers were ranked from the greatest to the least amount of reduction in test, producers whose shipments had the highest butterfat content were consistently in the upper half of producers having the largest bias. The reduction in test was increased under non-refrigerated conditions and also when the length of the compositing period was increased.



Here a driver is obtaining a milk sample for butterfat determination and placing it in the sample bottle.

Table 5. - Comparison of the average bias and the sample standard deviation¹ of the producers with eight highest and eight lowest average butterfat content²

Type of sample	Low test		High test	
	Amount of bias	Standard deviation	Amount of bias	Standard deviation
10-day refrigerated-----	+ .022	.013	-.088	.011
10-day non-refrigerated-----	-.023	.020	-.114	.011
15-day refrigerated-----	-.021	.013	-.0913	.011
15-day non-refrigerated-----	-.028	.011	-.101	.009
Average test		3.27		4.67
Number of producers----		8		8

¹Sample standard deviation is the amount of variability in the sample averages that could be expected from repeated sampling.

²The high butterfat content included those producers whose shipment had an average butterfat content of 4.3 percent or higher, while the lowest were those with a test of 3.4 percent or lower.

As an alternative to composite test results, average tests could be based upon the test of fresh samples taken from a limited number of shipments during each pay period.

Sample errors in test results based upon such a sampling program may be within plus or minus certain specified amounts for a known proportion of producers. Thus, when the variability in producer tests is known, the proportion of sample averages that will be within the specified amounts of the average can be computed. Table 6 lists the sample errors for specified test variabilities. When the producer's tests vary more, the sample error is increased and/or the proportion of sample averages included within the specified error will decrease.

The amount of bias that developed from the compositing procedures varied among producers. Producers with high butterfat content had an average reduction in test in relation to the average test of fresh sample for the same period of about $-.09$ percent for 15-day composite. Less reduction in test was evident for shorter periods and for producers with lower butterfat tests. However, Table 6 shows that variations from the average would not be expected to exceed the $.09$ downward bias for a large proportion of the sample averages if based upon 6 or even 4 fresh samples per month, since about 75 percent of the producers had a standard deviation of $.16$ percent or less. Further, the large sample error resulting from the compositing procedure would need to be considered.

Averages based upon tests of a limited number of fresh samples can be expected to fluctuate around the true averages. The inaccuracies of composites have evidence of bias. Since errors in estimating the true average based upon fresh sampling and testing are random in nature, they can be expected to be compensating in the long run. Errors in test results from composite samples would not be compensating.

Since bulk procurement is at present being used for large shipments, it offers a means for increasing the accuracy of producer tests by basing producer averages on a limited number of fresh tests. Producers using the bulk procurement system have relatively small fluctuations in test. Further, volume of milk per delivery is large. These are basic considerations in developing an accurate, low-cost testing program. Even small inaccuracies in tests make relatively large inaccuracies in producer payments since each producer has large-volume shipments. The small variations in the butterfat content from shipment to shipment reduce the error of sample averages based upon a limited number of fresh samples.

Based upon 1953 cost and rates of testing, it was found that cost per additional test varied from 8.3 to 12.5 cents, depending upon the size of the plant and/or the market, as reported in the study of butterfat sampling and testing programs for conventional can receiving operations previously mentioned. A downward bias of $.09$ percent or $.9$ of a "point" would result in a substantial reduction in producer payment with a cost of 10 cents per additional sample. For example, assuming that a

Table 6. - Proportion of sample averages that will be within specified amounts of the true average when based upon 2, 4, and 6 tests of fresh samples per month for stated amounts of variability¹

Amount of variability	Maximum differences from the average with two fresh tests that include the following proportion of sample averages			Maximum differences from the average with four fresh tests that include the following proportion of sample averages			Maximum differences from the average with six fresh tests that include the following proportion of sample averages		
	68 percent	95 percent	99 percent	68 percent	95 percent	99 percent	68 percent	95 percent	99 percent
.05-----	.033	.066	.099	.022	.043	.066	.017	.031	.049
.10-----	.066	.132	.198	.043	.085	.129	.031	.066	.095
.15-----	.099	.198	.295	.066	.129	.192	.049	.095	.142
.20-----	.132	.263	.392	.085	.171	.257	.066	.127	.190
.25-----	.167	.330	.492	.108	.214	.321	.080	.159	.238

¹Variability is in terms of standard deviation and refers to the variation in the butterfat tests of producers' milk shipments.

small producer with bulk procurement would ship 150 hundredweight of milk per month and composite test would reduce the test .09 percent, a butterfat differential of 8 cents per "point" would result in an underpayment of \$10.80. Even if fresh samples from each delivery on an every-other-day basis were tested assuming a cost of 10 cents per sample, the cost per month to the producer would only be \$1.50 ($\$0.10 \times 15 = \1.50).

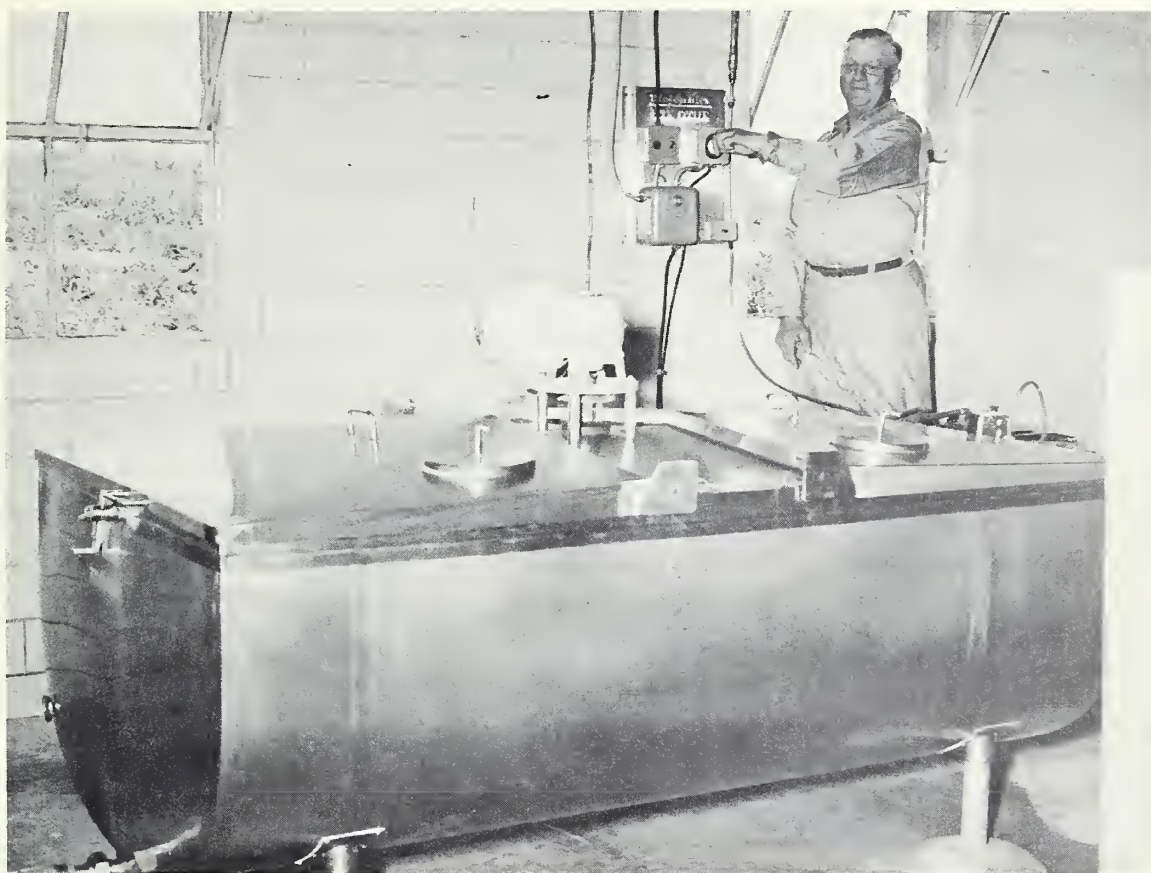
This illustrates that the usual volume of milk from producers using the bulk procurement system gives definite economic advantages to test results based upon a fresh sampling program. Test results with even .01 percent (one-tenth of a "point") downward bias would give a producer with every-other-day shipments of 1,250 pounds or more a payment about equal to sampling and testing from each shipment, assuming that the cost of the testing program is carried by the producer. Either a larger bias or greater volume of milk would be favorable to the fresh sampling and testing program.

The small variability in tests between milk shipments from the same producer would make it possible to base the average on less than one sample from each delivery and still achieve a high degree of accuracy for the producers. (Table 6.) Considering the random nature of such variability it is evident that in the long run a high degree of accuracy for each producer will be achieved. This study and the one previously mentioned showed that variability in producers' tests changed from month to month although these changes were within narrow ranges. However, when variability was computed as an average variability per month on an annual basis, the range in averages for all producers did not have as wide a range in variability as the averages in one month. Thus, the sampling error for averages of a limited sampling program can be expected to be less over a period of time than indicated by the variability in any one month.

MILK SOLIDS LOSS IN CAN AND FARM TANK

We also compared losses of both butterfat and total milk solids in conventional can procurement with losses in the bulk procurement system. In the bulk procurement system the driver measured the volume of milk in the farm tank. This measurement was converted to a weight basis. Losses in volume and milk solids occurring after this measurement were the purchaser's losses. In conventional can procurement the purchaser obtained the weight of the milk after it was received at the plant. Losses occurring before this were the producers' losses. Thus, the loss of milk solids shifted from the producer to the plant when procurement was shifted from conventional can to bulk procurement.

In determining the comparative losses between the two systems we used the following procedure. The driver thoroughly rinsed the farm bulk tank and incorporated all visible milk solids into the rinse water. He marked a container to indicate a fixed quantity of rinse water. He added water to obtain this same fixed quantity of rinse water from each farm bulk tank, and took a representative sample from this rinse water.



By agitating milk in the farm bulk tank for a minimum of 2 minutes, drivers were able to obtain an adequate blend. After the milk was agitated, drivers collected samples from selected positions in the farm tank for the laboratory tests.

Laboratory personnel analyzed the sample by the Mojonnier method to determine the butterfat and total solids content. A total of 65 rinse water samples were analyzed.

With conventional can procurement the receiving crew dumped the milk into the weigh tank in the customary manner. However, after dumping the milk they turned the cans upright rather than placing them in the can washer. A sample of milk from the weigh tank was taken and later tested by the Babcock method to determine the butterfat content. Then they rinsed the can covers and the empty cans that had been put in an upright position. All visible milk solids were incorporated into the rinse water. They obtained a representative sample of this rinse water and analyzed it for butterfat and total milk solids by the Mojonnier method. The total amount of water used in rinsing was weighed. Samples from 59 deliveries were analyzed. Both the volume of milk delivered and the number of cans were obtained.

From the butterfat determination of the milk samples and the total volume of milk, the total butterfat delivered was determined. By the use of the relationship between butterfat and non-fat solids, the total solids in the milk were determined.² From the Mojonnier determinations of the butterfat and total milk solids in the rinse water samples and the total weight of rinse water, the total quantity of butterfat and total milk solids were computed. The amount of butterfat and total solids in the rinse water were then computed as a percent of the total butterfat and as a percentage of the total milk solids.

The amount of milk left in the cans was not determined but only the amount of milk solids lost. The comparative results indicated the net effect upon the producer and purchaser at the place of sale. With conventional can procurement the average percentage butterfat loss to the producer was .429 percent of the total butterfat, and .404 percent of the total milk solids (Table 7.) With bulk procurement the producer had no loss of butterfat or other milk solids since the purchaser measured the volume in the farm tank. However, the purchaser had a loss of .109 percent of the total butterfat and .077 percent of the total milk solids after the milk was transferred to the bulk tank truck.

The ratio of butterfat to total solids in the milk was 1 to 3.29 for conventional can procurement and 1 to 3.26 for bulk procurement. However, in the test of the rinse water and ratio was 1 to 3.16 and 1 to 2.61 for the can and bulk procurement systems, respectively. For both systems

²Jacobson, M. S. Butterfat and Total Solids in New England Farmers Milk as Delivered to Processing Plants, Jour. Dairy Science, 19; 3, pp. 171-176, 1936.

For a compilation of formulas estimating total solids from butterfat test see Herrmann, L. F. Indirect Estimates of the Solids-Not-Fat Content of Milk, The Basis for and History of, Published Methods and Equations, U. S. Agr. Mar. Serv., March 1954.

Table 7. - *Comparison of percentage milk solids losses in milk between bulk and conventional can systems*

Source of losses	Number of tests	Percentage loss		
		Butterfat	Nonfat	Total milkk solids
Can procurement-----	59	.429	.404	.412
Bulk procurement:				
Actual-----	65	.109	.077	.087
Theoretical ¹ -----	-	.061	.058	.059

¹If losses are in direct proportion to the wetted surface the loss for milk procurement would be about one-seventh as much as for can procurement. The theoretical loss is based upon this relationship.

the loss of butterfat was relatively larger than for total milk solids. Further, the milk solids loss in the bulk procurement system had relatively more butterfat than did the milk solids loss with conventional can procurement. However, the total loss of butterfat and the total loss of milk solids were less for bulk procurement. The ratio of fat to total milk solids indicated that the rate of butterfat losses were somewhat higher than for total milk solids. Percent of butterfat and total solids losses for the can system were about equal to the percent volume losses reported in other studies for the conventional can procurement system.³ Thus, the procedure used gave reliable data for making comparisons.

The amount of milk solids lost varied. The range in variability in the amount of loss per producer was affected by (1) the volume of milk delivered (2) number of cans and (3) the butterfat content. These three factors accounted for about 66 percent of the variation in losses among producers.

This study did not investigate all of the losses from farm to plant by both methods. For example, we did not include losses in-transit with can procurement and losses of milk solids adhering to the bulk tank truck. However, the comparative analysis highlights some major shifts in assuming losses in milk marketing. The producers' losses are materially reduced. The losses of milk solids during the plant's milk receiving operation are entirely eliminated as an individual producer's loss. However, the losses for the plant must be computed from the farm tank through its entire process.

Thus, the normal plant loss will be increased by losses incurred at the farm tank and any possible losses from the farm to the point in the plant comparable to the conventional can procurement system. For a cooperative, this means a pooling of losses instead of each individual producer carrying his own losses as with can procurement.

From the analysis of losses the following conclusions can be made:

1. Using the bulk system reduced losses of butterfat and total milk solids incurred by the producer by at least .4 of one percent.
2. Plant losses should be computed from the point of purchase at the farm tank through the entire plant operation. The bulk system would increase such losses by about .1 of one percent. In addition, certain in-transit milk losses would be incurred.

³Schwarzkopf, V. Little Drops of Milk Make a Mighty River. Paper presented at the Milk Industry Foundation in Detroit, Mich. Oct. 1951.

_____ The Milk Can's Future and Its Relation to Quality. Milk Products Jour. p. 46. Feb. 1954. (Findings of the Dairy Industry Committee on Dairy Waste.)

Unpublished reports of other studies indicate about the same percentage loss by volume.

3. The quantity of butterfat lost was relatively larger than for other milk solids although this difference was quite small.

4. The bulk procurement system reduced overall losses of milk solids. (This assumes that losses in-transit from farm to plant would be comparable in the two systems.)

5. The ratio of losses of butterfat to total milk solids losses was about the same for both the bulk and can procurement system. However, since total butterfat loss was relatively larger for the can system than for the bulk system, this greater loss must either be reflected as a loss in volume or a reduced test. The amount of this reduction would be small.

APPENDIX A

In this study of butterfat sampling and milk solid losses in farm tank, drivers taking the samples followed the same general procedure they ordinarily do. This included icing sample storage when necessary, using properly marked sample bottles, measuring the quantity of milk, agitating, making necessary hose connections and the other routine aspects of bulk tank pickup.

Drivers performed the following jobs and recorded data on the forms provided. Details of the procedure also follow.

1. Recorded the quantity of milk.
2. Made observations for evidence of churning.
3. Recorded time agitation was started.
4. Obtained customary sample.
5. Recorded time.
6. Obtained the four samples (one duplicate) from the three designated positions as indicated by (Appendix A, Table 1.)
7. Recorded the time.
8. Obtained one rinse water sample per route.

(Caution: It is important to obtain samples in the order designated from the position specified, and after the agitation time for the individual tank. For details of the procedure refer to the explanation.)

Detailed Procedure for Drivers in Obtaining Samples

We gave these specific directions to the drivers:

1. Record quantity of milk.
2. Use the black spatula provided and pass this through the milk to detect churning. Repeat this after last sample has been obtained. Observe the sides of the tank and the measuring stick to detect churning. Evidence of churning are white particles that have a butter-like consistency. These particles will cling to the spatula, sides of the tank and to the measuring stick.
3. Record the time when agitation is started.

4. Obtain one sample in the customary manner. This sample will be about 120 cc. sample or equivalent to two full dippers. This will be one full dipper from each end of the tank.

5. Record the time, after customary sample is taken.

6. From each of the positions designated as A, B, and C, as indicated on the diagram of the farm bulk tank (on page 23,) obtain a 60 cc. sample of milk. For each delivery of milk obtain a duplicate sample from one of the positions. The duplicate sample will be the additional sample bottle for that position. The laboratory personnel will provide the appropriately marked bottles. For example, the duplicate sample for the first day will be from position A. In addition to the A sample, another sample from the A position should be obtained and placed in a bottle marked A1, provided by the laboratory. On the second delivery, the duplicate will be from position B and will be put in the sample bottle designated B1. The duplicate for the third day will be from position C and the bottle will be marked C1.

7. It is assumed that agitation time affects the adequacy of blending. For this reason the following procedure should be used. On the first pickup from each individual farm tank obtain the agitation time from the beginning of agitation to the time the customary sample is taken and also the time when the last additional sample is taken. When the duplicate sample is taken, it should be taken as soon as possible after the first sample from that position is obtained and as close as possible to the same position. The same amount of agitation time should be used for that tank for each milk pickup during the 61-day period of the project. Drivers should obtain an agitation period for each tank that approximates their present time requirements. Thus, the only precaution is that this length of time be followed closely during the rest of the study. As a practical measure it may be desirable to make a record of agitation time for each farm tank.

The agitator will be operating while all samples are being obtained. To standardize the time conditions, the samples should be taken according to the patterns in Appendix Table 1. The letters refer to the position in the tank. Since routes are operated under every-other-day pickup the dates are for two days but actually refer to the successive pickups. Record the time when agitator is started, when the customary sample is taken and when the last sample is obtained. In obtaining samples follow the schedule. Laboratory personnel will provide the appropriately marked bottles, including the duplicate position sample bottles.

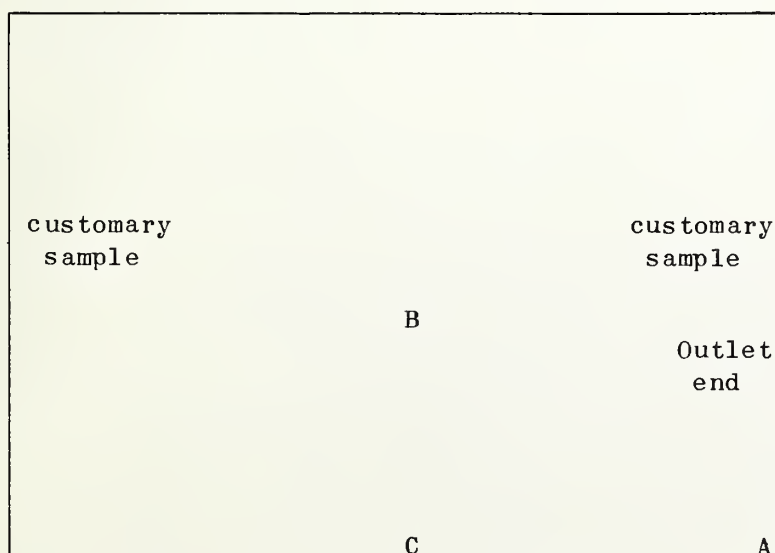
With the designation as given, it is not necessary to locate the position on any diagram. It is important to obtain samples from the three points designated.

Appendix A, Table 1. - Schedule of order for obtaining position samples¹
(Used on all pickups for the days designated)

Date	Order of sampling			Date	Order of sampling		
	1st	2nd	3rd		1st	2nd	3rd
June 1 - 2---	AA1	B	C	July 1 - 2--	A	B	CC1
3 - 4---	BB1	C	A	3 - 4--	B	C	AA1
5 - 6---	CC1	A	B	5 - 6--	C	A	BB1
7 - 8---	A	EB1	C	7 - 8--	AA1	B	C
9 - 10--	B	CC1	A	9 - 10-	BB1	C	A
11 - 12--	C	AA1	B	11 - 12-	CC1	A	B
13 - 14--	A	B	CC1	13 - 14-	A	BB1	C
15 - 16--	B	C	AA1	15 - 16-	B	CC1	A
17 - 18--	C	A	BB1	17 - 18-	C	AA1	B
19 - 20--	AA1	B	C	19 - 20-	A	B	CC1
21 - 22--	EB1	C	A	21 - 22-	B	C	AA1
23 - 24--	CC1	A	B	23 - 24-	C	A	BB1
25 - 26--	A	BB1	C	25 - 16-	AA1	B	C
27 - 28--	B	CC1	A	27 - 28-	BB1	C	A
29 - 30--	C	AA1	B	29 - 30-	CC1	A	B
				31-----	A	BB1	C

¹Customary sample as now obtained will be taken prior to the additional samples.

Position Designation: The letters A, B, and C, refer to the positions as located below. While farm tanks vary in shape, samples should be obtained as closely as possible from the positions as designated. It is particularly important to obtain duplicate samples of a position from the same spot that the first sample of that position was obtained.



Note: Take sample A as close as possible to the corner; sample B as close as possible to the agitator and sample C close to side in the middle of the long side of the tank. The diagram illustrates the relative positions.

8. The sample bottle designation will be the producer's regular number for the customary sample and this number plus one of the letters A, B, or C to distinguish each of the three positions. Place samples in bottle storage compartment on the truck.

9. Each driver should obtain one rinse water sample per route each day. The rinse water sample should be obtained in the following manner:

- (a) Thoroughly rinse the farm tank. See that all milk solids adhering to the tank walls are incorporated into the rinse water.
- (b) Obtain 60 cc., one full dipper sample from the thoroughly agitated rinse water. Place rinse water in the sample bottle marked with producer's number and letter "R".
- (c) Accurately measure the total amount of rinse water and record. Place rinse water sample in the sample bottle storage compartment in the truck.

10. From each route, obtain the rinse water from producer's tanks in a consecutive manner. That is, on the first pickup obtain the rinse water sample from the first producer, on the second pickup obtain the rinse water sample from the second producer, and so on until one sample from each producer on the route is obtained. Continue the cycle throughout the course of the study, in order to obtain approximately the same number of rinse water samples from each producer. During the 61-day period, there would be from 3 to 6 rinse water samples from each producer depending upon the number of producers on each route.

11. After delivery of the milk at the plant, place samples of the milk in the refrigerator. It may be convenient for the driver to have someone (for example, the mail clerk) place samples in the refrigerator, but it is the responsibility of the driver to take proper care of the sample. Warm weather quickly sours the samples and thereby decreases the accuracy of the tests. It is the responsibility of the truck driver to deliver acceptable samples to the laboratory.

12. The daily record form provided should be left with the sample bottles.

Specific Procedure for Laboratory Personnel

We gave these directions to the laboratory personnel:

- 1. Obtain samples and daily record sheet from the refrigerator where drivers have placed them.
- 2. Observe sample for evidence of churning or sour milk.

3. The sample taken in the customary manner should be broken into composite samples. One composite sample will be a 15-day composite sample. This sample will be the first 8 consecutive deliveries with skip-day pickup for the first 15-day sample of the month. The second 15-day composite sample will be the remaining deliveries for that month. Tests will be run within one day after last sample for the composite is obtained. From the fresh milk sample 15 cc. from each delivery will be placed in the composite sample.

The second composite sample will be a 10-day composite consisting of 15 cc. from each of five consecutive deliveries. Three such 10-day composite samples will be made each month. Tests of composites will be run within one day after the last sample for the composite has been obtained. These composite samples should be stored in the refrigerator at a temperature of between 40 and 50 degrees Fahrenheit. These samples should not be allowed to fluctuate in temperature. Therefore, the sample should not be out of the refrigerator in excess of one hour at any time. Store both the 10 and 15-day composites in refrigerator.

In the same manner as described above make another 10-day and another 15-day composite from the customary sample. These composites will be stored under present storage conditions.

All composite samples will be preserved by the addition of one corrosive sublimate tablet containing 0.3 grams of mercuric chloride and should be stoppered tightly.

4. All samples including the customary sample will be tested on a fresh milk basis for each delivery. That is, a total of five (the customary sample, plus four additional samples) fresh samples from each producer's delivery will be tested during the 61-day period.

5. Test samples according to the following procedure:

A. Preparing Samples for Testing:

(1) Fresh sample:

- a. Immerse in a water bath to slightly above the level of milk in the bottle and heat to 95-100 degrees F. Water bath should be controlled at 105 degrees F.
- b. Mix sample by rotating the container in one plane until the sample is thoroughly blended.
- c. Pipette immediately. Pipetting at 90-100 degrees F. is a deviation from the official methods as outlined in "Official and Tentative Methods of Analysis." Since the primary interest in this study is the day-to-day variation in butterfat content of the milk, as long as all samples are measured at the same temperature, no error should be introduced into the study as a result of this deviation.

(2) Composite samples:

- a. Immerse in a water bath to slightly above level of milk in bottle and heat to 95-100 degrees F. Water bath should be controlled to hold water at 105 degrees F.
- b. Mix sample by rotating the container in one plane until the milk is thoroughly blended. If fat adheres to sides of bottles and bottom of rubber stoppers dislodge with a wiping disk.
- c. Pipette immediately.

B. Testing Procedure.

- (1) As soon as the sample is properly mixed, fill a 17.6 ml. pipette to above the mark on the draw tube.
- (2) Adjust the upper surface of milk to the graduated mark on the draw tube.
- (3) Insert stem of pipette into neck of test bottle. Allow milk to drain not less than 10 seconds. Blow last drops from tip into test bottle.
- (4) Cool milk in test bottles to within the temperature range of 68-70 degrees F.
- (5) Add 17.5 cc. of sulphuric acid (standardized 1.82 - 1.83 Specific Gravity). Acid should be within the temperature range of 68-70 degrees F. As acid is added the test bottle should be held at an angle and turned so that any milk which clings to the side of the neck is washed into the bulb of the test bottle.
- (6) Immediately after acid is added, mix contents of the test bottle by gently rotating bottles for at least 3 minutes.
- (7) Place bottles in centrifuge and whirl bottles 5 minutes after the centrifuge has reached full speed.
- (8) Stop centrifuge and add soft water, the temperature of which should be 140-160 degrees F., until the mixture in the bulb of the test bottle is raised to just below the base of the neck of the bottle.
- (9) Whirl bottles 2 minutes.
- (10) Add soft water, temperature 140-160 degrees F., to bring fat column within graduated neck.

- (11) Whirl bottles for 1 minute to collect the fat into the neck of the bottle.
- (12) Immediately place bottles in a water bath which is controlled at 135-140 degrees F. and hold for 5 minutes.
- (13) Remove drops of water from the neck of the test bottle and read immediately. Measure the fat column from the lowest to the highest point including the menisci.

C. Duplicate Tests.

- (1) Duplicate tests should be made on samples showing a variation of 0.3 percent or more from the test of the sample for the preceding period, i. e., in case of fresh samples, the test of the sample of the previous day's delivery; in the case of composite samples the test of the corresponding composite sample for the preceding period. Record the first run in the normal manner, but record the duplicate run with a circle around it.

D. Equipment Specifications.

(1) Sampling dippers:

- a. A 60 cc. dipper for taking sample of milk will be provided for the truck driver.
- b. A 15 cc. dipper for breaking original sample into composite samples will be provided for the laboratory personnel. The 17.6 ml. pipette can be used as an alternative measuring device.

(2) Sample bottles:

- a. Eight-ounce bottles with rubber stoppers, preferably attached to the bottle. Each bottle should be clearly identified with the producer's complete number.

(3) Pipettes:

- a. Should be so graduated that when filled to the etched line on its stem it holds 17.6 cc. of milk and delivers 18 grams or 17.5 cc. at 68 degrees F.
- b. Should meet Bureau of Standards specifications.

(4) Test bottles:

- a. Should read accurately for an 18 gram sample of milk and have a total graduated face reading to 8 percent with the smallest unit of calibration being 0.1 percent.
- b. Should meet Bureau of Standards specifications.

(5) Centrifuge:

- a. Should be electrically driven at a speed such as to create 31 pounds of centrifugal force.
- b. Chamber should be automatically maintained at a temperature of 130-135 degrees F.
- c. Should be equipped with a speed indicator and thermometer.

(6) Water baths:

- a. For warming samples - should be controlled to hold water at 105 degrees.
- b. For tempering fat columns - should be controlled to hold water at 135-140 degrees F.

(7) Acid measure:

- a. Acid bottle should be so graduated as to deliver 17.5 cc. of sulphuric acid.

6. Test rinse water samples according to the following procedure:

The rinse water samples will be tested by the standard Mojonnier method for determining total solids and butterfat. Each day for the month of June, two producer rinse water samples, one from each route, will be tested. During the month of July, two producer rinse water samples and an additional two samples of rinse water from 10-gallon cans will be tested. One-fourth of all these rinse water samples will be tested for butterfat content as well as total solids content. A total of 184 samples will be tested by the Mojonnier method for total solids and of these 184 samples, 46 samples will be tested for butterfat content as well as total solids.

The rinse water sample from conventional 10-gallon cans will be obtained from two producers per day during the month of July as follows:

- (1) As soon as each can of the producer's milk is dumped and before the can has drained, turn the can upright. Do this with each can of the producer's delivery for that day.
- (2) Obtain a 60 cc. fresh milk sample from the weigh tank for butterfat determination. This sample will be tested as a fresh milk sample as previously described.
- (3) Thoroughly rinse each can and can cover of the producer's delivery for that day.

- (4) Obtain a 60 cc. sample of the rinse water.
- (5) Obtain the weight of rinse water used and record the quantity. Also record the number of cans and covers rinsed.
- (6) By the accepted Mojonnier method make a test for total solids. For one-fourth of all samples make a butterfat, as well as total solids determination.

APPENDIX B

The components of variances can be estimated from an analysis of variance. The following table gives the analysis of variance for a single producer in this study.

<u>Source of variation</u>	<u>Degrees of freedom</u>	<u>Mean square</u>	<u>Average value of the mean square</u>
Between deliveries	$d - 1$	M.S. (D)	$\sigma^2 + k_1 \sigma_p^2 + k_2 \sigma_d^2$
Between positions within deliveries	$pd - d$	M.S. (P)	$\sigma^2 + k_1 \sigma_p^2$
Within positions within deliveries	$n - pd$	M.S. (E)	σ^2
Total	$n - 1$		

Where σ^2 = the unexplained variance

σ_p^2 = the variance due to positions

σ_d^2 = the variance due to deliveries

d = number of deliveries

p = number of positions

n = number of samples or butterfat tests

$$1/k_1 = \frac{1}{pd-1} \left(\sum_{i=1}^{pd} n_i - \frac{\sum_{i=1}^{pd} n_i^2}{\sum_{i=1}^{pd} n_i} \right)$$

where n_i is the number of samples taken from the i th position

and $\sum_{i=1}^{pd} n_i = n$

$$k_2 = \frac{n}{pd}$$

1/ If an equal number of samples had been taken from each position k_1 equaled $\frac{n}{pd}$.

The estimates of σ^2 , σ_p^2 , and σ_d^2 are easily obtained from the above analysis of variance. σ^2 equals the mean square for within positions within deliveries (M.S.(E)). To obtain an estimate of σ_p^2 we compute

$$\frac{\sqrt{\text{M.S.}(P) - \text{M.S.}(E)}}{k_1}$$

Similarly we obtain an estimate of σ_d^2 by computing

$$\frac{\sqrt{\text{M.S.}(D) - \text{M.S.}(E)}}{k_2}$$

The results of these estimates are given in Appendix B, Table 1.

Appendix B, Table 1. - Comparison of the components of variability¹ and the effect of average butterfat tests, volume of milk and size of tank on the components 26 producers June, July 1953

Producer	Butterfat test	Volume of milk	Size of tank	Estimated within position variance component	Estimated between position variance	Estimated component of variance in actual butterfat content
	<i>Percent</i>	<i>Pound</i>	<i>Gallon</i>			
1.	5.1	656	150	.001724	.000002	.057399
2.	4.8	698	200	.012917	.001362	.019968
3.	4.6	1155	300	.001042	² .000603	.013288
4.	4.6	1189	300	.001667	² .001089	.010051
5.	4.5	1122	200	.007250	² .013462	.035214
6.	4.5	1250	200	.001532	.000174	.017244
7.	4.4	742	150	.002661	.000258	.037455
8.	4.3	1214	200	.001048	.000197	.026791
9.	3.6	1298	200	.001625	.000064	.023422
10.	3.6	1023	200	.001290	² .001365	.008915
11.	3.6	966	200	.001532	.000265	.014511
12.	3.5	1491	200	.000927	² .000734	.014364
13.	3.5	1190	200	.001492	.000568	.015830
14.	3.5	1494	300	.000847	.000431	.009615
15.	3.5	1274	300	.000647	.000938	.045573
16.	3.5	1329	300	.001290	.001128	.016626
17.	3.5	1275	300	.001509	.000239	.010131
18.	3.5	1245	300	.001573	-.000045	.026888
19.	3.4	1346	300	.001290	.000098	.023456
20.	3.4	1016	200	.001331	² .000719	.020300
21.	3.4	2286	400	.001583	.000165	.009630
22.	3.4	1314	200	.000875	² .000819	.045300
23.	3.4	2804	500	.000780	.000050	.013788
24.	3.3	2636	600	.001210	-.000159	.008752
25.	3.2	1451	300	.001417	.000208	.015050
26.	3.1	3287	600	.000974	.000288	.012988
Average	3.8	1483	-	.002001	.000942	.021252

¹The variability is listed as the variance. To obtain the standard deviation the square root should be used.

²Significantly different from zero, thus differences among positions were not due to chance alone.



